
Author: Michael J. Motyl/0C/Caterpillar

Customer Group: 328-00

Author's Phone: 86269

Cust. Div./Location: Def & Fed Prod

Facility: Technical Services Division

Customer Phone:

Department: Engine Materials Technology

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| (*) Normal |
( ) HOT!

Status: Completed

Piece Part Information

Part No: 148-1973

Part Name: Flywheel Housing

Commodity Group: Castings

Matls Specs: 1E1047

Part Group - Top Level: Housings

Process Specs: T6

Part Group - Subset: Flywheel

Supplier/Supplier Code:

Assembly No:

Design Control: W129

Assembly Name:

Heat/Cast Code:

Serial Identification:

Date Code:

Product Information

Serial No: VIN: 10TFAWD261S070061

Product Group: Engine - 3100 Family

Build Date: 11/10/2000

Model Specifics: C-12 Engine

of Operation:

General Application: Truck

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Application Specifics:

Product Health Information

Parts Return Follow-up No: Claim No:

Link:

Dealer Code: D530 Dealer Name:

Failure Mode: Ductile

Abstract/Introduction:
Nashville Ready Mix discovered a loose fit-up of the flywheel housing to the C-12 engine block after 42,171 miles of service in a cement mixer built by Oshkosh. Bolts broken off inside the block were revealed after the transmission was removed from the housing. Two cracks were also observed in the lower right area of the flywheel housing. A similar failure occurred in almost half (6 of 15) of the initial order of Oshkosh trucks built for this customer. A repetitive occurrence of the failure was experienced by the same 6 trucks. The failure submitted for this investigation was part of the next 1000 trucks that exhibited a much lower failure rate (3 of 1000 trucks). It is important to note that the failure rate for on-highway trucks with a similar flywheel housing assembly was extremely low for the last 5 years.

The material specified for the flywheel housing is 1E1047 aluminum with a T6 heat treatment. The steel bolt requires a quench and temper heat treatment in accordance with 1E1725.

EMT was requested to perform the failure analysis of the bolts and flywheel housing.

Observations & Results:

Bolts

The bolts satisfied the Metallurgical requirements specified in 1E1725.
The failure mode of the bolts was unidirectional bending fatigue at the first contact thread.

Flywheel Housing

The tensile and yield strength of the casting satisfied the requirements specified in 1E1047 for the T6 heat treatment.
Ductile fractures in the housing resulted from a single load event.

Conclusions:

A bending moment from the cement mixer application was the likely cause of the fatigue failure of the bolted joint between the flywheel housing and engine cylinder block. The evidence of fatigue observed on the bolt fractures combined with acceptable bolt properties suggests that the load (cyclic) from this cement mixer application exceeded the fatigue strength of the bolts.

The ductile nature of the cracks in the flywheel housing indicated that a single over load event occurred after the bolts began to fail.

Casting defects were not observed on the fracture and the tensile samples machined from the housing satisfied the 1E1047 T6 specification for strength. The ductile fracture of the flywheel housing indicated that the low percent elongation was not a significant factor in the cause of the failure.

Recommendations/Corrective Action/Follow-up:

The results from this investigation support the engineering path of the evaluating the loading conditions applied to the bolted joint tested in a cement mixer. The stress/strain analysis of the bolts and frame would provide useful information for the 8D process.

Discussion:

Bolts
Figure 1 shows the flywheel housing on the engine with 7 fractured bolts still lodged in the cylinder block. EMT received 6 of the 7 fractured bolts for evaluation. The secondary damage observed on the inside of the aluminum flywheel housing shown in Figure 2 was due to a fractured bolt trapped between the housing and flexplate. The thread impressions inside the holes (i.e.: Figure 3) indicated that the head portion of the fractured bolt was sticking out of the hole when struck by the flexplate or possibly a bolt driven by the flexplate. At least 3 of the holes identified by the green markers (Embedded image moved to file:
pic18762.jpg) in Figure 2 exhibited these marks.

SEM analysis of the fracture surface of the failed bolts returned from service revealed the following:

|---|
| Bolts #1 through #3 - A fatigue fracture was initiated at the first |
| contact thread due to unidirectional bending (Figures 4-6). The |
| propagation of the fatigue crack in one direction indicated that the |
bolts were not loose during the failure.
Bolt #4 - Figure 7 shows the fatigue structure at the origin of the
fracture that occurred after the bolt backed out of the block.
However, before the bolt backed out, a fatigue crack formed at the
first contact thread while the bolt was fastened (Figure 8). This
crack propagated 4 mm before the bolt rotation of the two threads and
complete failure occurred. It is likely that the bolt backed out as a
result of the movement from the flywheel housing.
Bolt #5 - A fatigue crack was observed in the first contact thread
without the complete fracture of the bolt. An example of the etched
pits on the surface of the bolts from a supplier cleaning operation is
shown in Figure 9. The pit observed on the thread root surface of
this bolt acted as crack initiation sites for the fracture. The effect
of the pits on the engine failure was considered insignificant.

Metallurgical

The metallurgical evaluation of the failed bolts showed that the hardness and hardness traverse satisfied the requirements specified in 1E1725. The core hardness of Rc 38 for two of the failed bolts satisfied the specified range of Rc 33 - 39. The flat curve of consistent hardness from surface to core showed that the surface satisfied the requirements for decarb/recarb.
These results indicated that the bolts received the required heat treatment.

Flywheel Housing
Figure 10 shows the location of the cracks observed in the flywheel housing. The orientation of the cracks with respect to the secondary damage that occurred from the head of a bolt driven into the aluminum housing by the flexplate is shown in Figure 11. The same cracks that propagated from the block side of the flywheel housing are shown in Figures 12 and 13. The cracks initiated from the bolt hole and port hole are shown in Figure 14. SEM analysis of the bolt hole fracture shown in Figure 15 revealed that a ductile fracture occurred from a single loading event. The ductile fracture was initiated on the block side of the housing and propagated to a shear lip on the flywheel side. It is likely that the load came from the impact of the bolt driven by the flexplate on the inside of the housing.

Metallurgical
The results from the two 0.350 inch diameter tensile samples machined from the housing satisfied the tensile and yield strength requirements specified for 1E1047 material with a T6 heat treatment. The tensile strength values of 245 and 252 Mpa exceeded the 207 Mpa minimum specified for a sample selected from any area of the permanent mold casting. The 138 Mpa minimum yield strength requirement was also satisfied by the 203 and 207 Mpa test results. The low elongation values of 2.2 and 1.8 % (spec 3 %) were consistent with an unacceptable heat treatment that was corrected since the time of this engine was built. The low elongation was not considered a major contributor to the failure because sufficient ductility was evident by fracture surface. The average hardness of 80 BHN tested with a 500 Kg load and 10mm ball indenter was equivalent to the typical value of 80 BHN provided in the specification.

Summary

Based on these results the bolts failed first due to fatigue. The unidirectional bending mode of failure indicated that the bolts were not loose at the time of failure. Further investigation of the structural loading conditions of the cement mixer is required to prevent future engine failures.

Attachments:
(See attached file: Figure 1 Failed Bolt Locations.JPG)(See attached file: Figure 2 Flywheel Side of Housing.JPG)(See attached file: Figure 3 Flywheel Housing Mechanical Damage.JPG) (See attached file: Figure 4 Bolt 1 Fatigue Fracture.JPG)(See attached file: Figure 5 Bolt 2 Fatigue Fracture.JPG)(See attached file: Figure 6 Bolt 3 Fatigue Fracture.JPG) (See attached file: Figure 7 Bolt 4 Fatigue Fracture.jpg)(See attached file: Figure 8 Bolt #4 Cracks.doc)(See attached file: Figure 9 Bolt 5 Etched Pits.JPG) (See attached file: Figure 10 Flywheel Housing Cracks.JPG)(See attached file: Figure 11 Flywheel Housing Crack Orientation.JPG)(See attached file: Figure 12 Block Contact Face.JPG)
(See attached file: Figure 13 Housing Crack Orientation.JPG)(See attached file: Figure 14 Fractured Holes.JPG)(See attached file: Figure 15 Housing Fracture Surface.JPG)

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Justin & Bill,

See note below. Jim Harrington at Freightliner has put together some Pro-E solid models of the Sterling truck model we are testing, along with the C-12 engine. Fly Hsg and Trans - with associated mounts. We will need to ask Jacob Jabs (Cat) or Muthu Trichy to manipulate those files and produce graphics that we would need for presentation purposes. I would suggest the following views:

1) Top view showing Engine, Fly Hsg, Transmission, Frame Rails and Mounts.

2) Right side view showing Engine, Fly Hsg, Transmission, Frame Rails and Mounts.

3) Left side view showing same as above """"""

4) view looking from Drivers side Rear towards front that shows a good view of Trans/Fly hsg mounts to frame rails, but also shows enigne.

Do you have any ideas of what other type of graphics you would like plotted?

Rich Bowes

CPI Supervisor
On Highway Engine Department
(309) 578-7028 FAX (309) 578-2437
Internet E-Mail: "Bowes_Richard_E@Cat.com"